

CHAPTER 6

DISTILLATION/CONDENSATION TECHNIQUES

6-1. General. Distillation/condensation is the most common desalination process. More than 70 percent of all desalination facilities in use today employ some variation of the distillation/condensation process.

6-2. High-temperature distillation. High-temperature distillation facilities that operate at temperatures greater than 205 degrees Fahrenheit are the most prevalent desalination facilities in the world today. There are three methods of vaporization: submerged tube vaporization; flash vaporization; and thin-film vaporization. These methods are illustrated in figure 6-1. Submerged tube vaporization is the least efficient vaporization technique, but it allows for easy maintenance. This type of vaporization system is most often used in exhaust gas waste heat recovery distillation systems. The flash vaporization technique is presently the most common technique in existing distillation units. The impact of sprayed hot brine within the evaporator unit causes both erosion and corrosion of most metals. Using a thin-film spray vaporization process, the raw water is introduced at slightly less than atmospheric pressure through an orifice onto heat exchanger tubes for immediate vaporization. The corrosive environment is reduced from the flash vaporization system, but scaling can occur on the heat transfer surfaces. These vaporization techniques are used in the two major high-temperature distillation processes, multiple-effect (ME) evaporation, and multistage flash (MSF) evaporation.

a. Multiple-effect evaporation units. To maximize thermal energy efficiency within a distillation/condensation system, several units or effects are used. The heat from the condensation step of one effect is used to supply vaporization heat for the following effect. The next effect is a slightly lowered pressure and temperature. This gradual reduction by heat transfer results in a much greater yield of product water from a given quantity of thermal energy. A typical multiple-effect evaporation unit is shown in figure 6-2.

b. Multistage flash-evaporation units. Distillation technology was advanced through the development of multistage flash evaporation units. Stages of flash evaporation are operated using heat from an external source. Pressure is reduced gradually in each successive stage to continue flash operation at successively lower temperatures and pressures. Because scaling is not a serious problem, this design has become the most prevalent distillation process. A typical multistage flash-evaporation unit is shown in figure 6-3. Although internal scaling is not a great

problem, corrosion of flash-evaporation units is of concern.

6-3. Low-temperature distillation. Distillation/condensation facilities that operate at temperatures less than 205 degrees Fahrenheit are low-temperature units. In situations where waste heat is plentiful, low-temperature waste-heat-recovery evaporation units are used. A waste-heat-recovery unit is shown in figure 6-4. For onshore application, low-pressure waste steam from power generation facilities can provide the necessary thermal energy for desalination systems. The most recent developments in distillation/condensation technology involve the use of waste heat or low-pressure steam with evaporation units and a mechanical vapor compression system. Multiple stages then derive the maximum vapor and product water production from the system.

6-4. Mechanical distillation. The use of mechanical methods for vapor production and heat transfer can result in a highly efficient desalination system. These systems operate at temperatures less than atmospheric boiling point and use a variety of methods to vaporize raw waters. These mechanical processes commonly use multiple effects to maximize the efficiency of the applied mechanical energy.

a. Vapor compression. The technique of vapor compression uses a mechanical energy source, such as an engine or electric motor, to power a compression turbine. This turbine draws vapor from the distillation vessel and compresses it, which raises the temperature of the exhaust vapor. The vapor is then passed over a heat exchanging condenser, where it returns to the liquid state as product water. The heat removed during condensation is returned to the raw water to assist in the production of more vapor. The more recent vapor-compression multiple-effect units produce a concentrated brine byproduct that has had its excess heat reduced by the multiple effects.

b. Waste heat. Adding waste heat to vapor compression systems results in a highly efficient

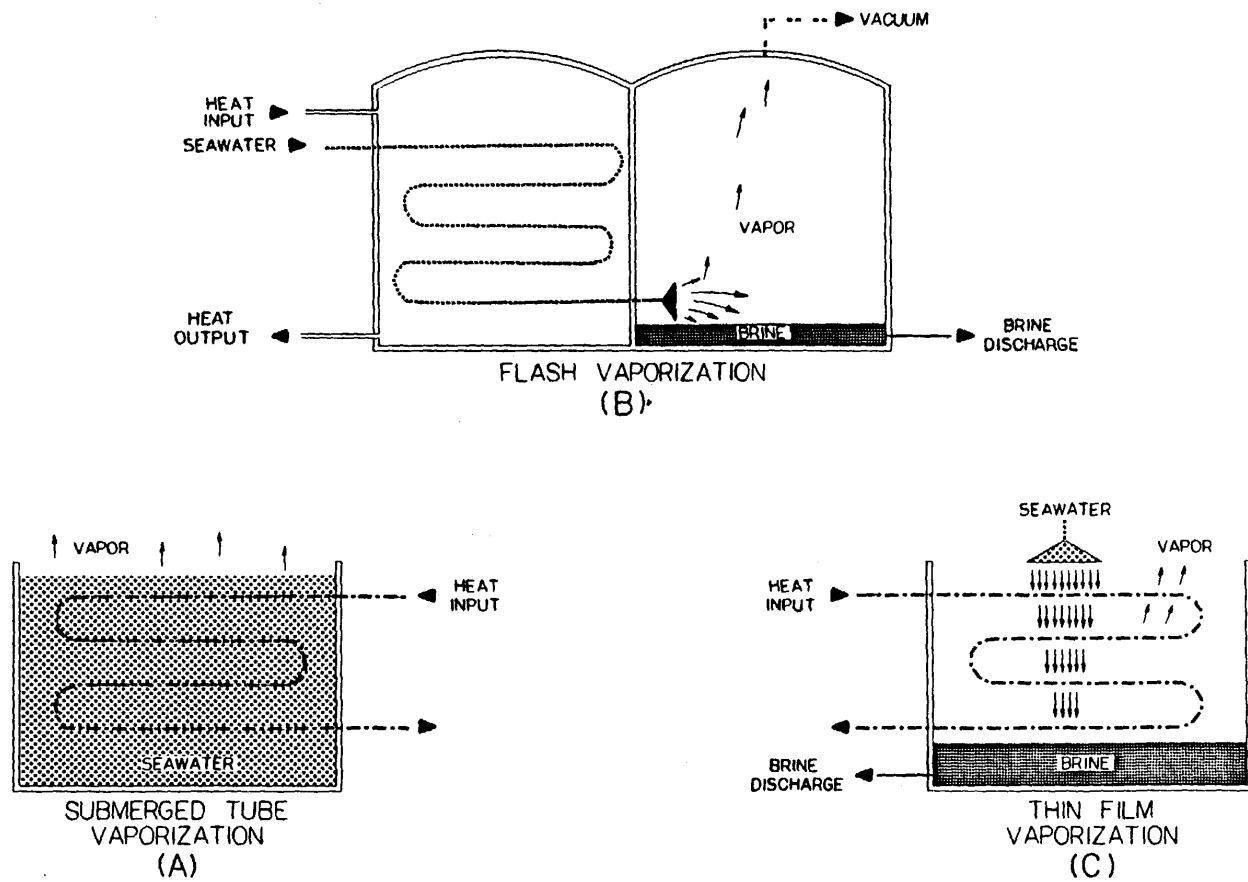


Figure 6-1. Three methods of vaporization.

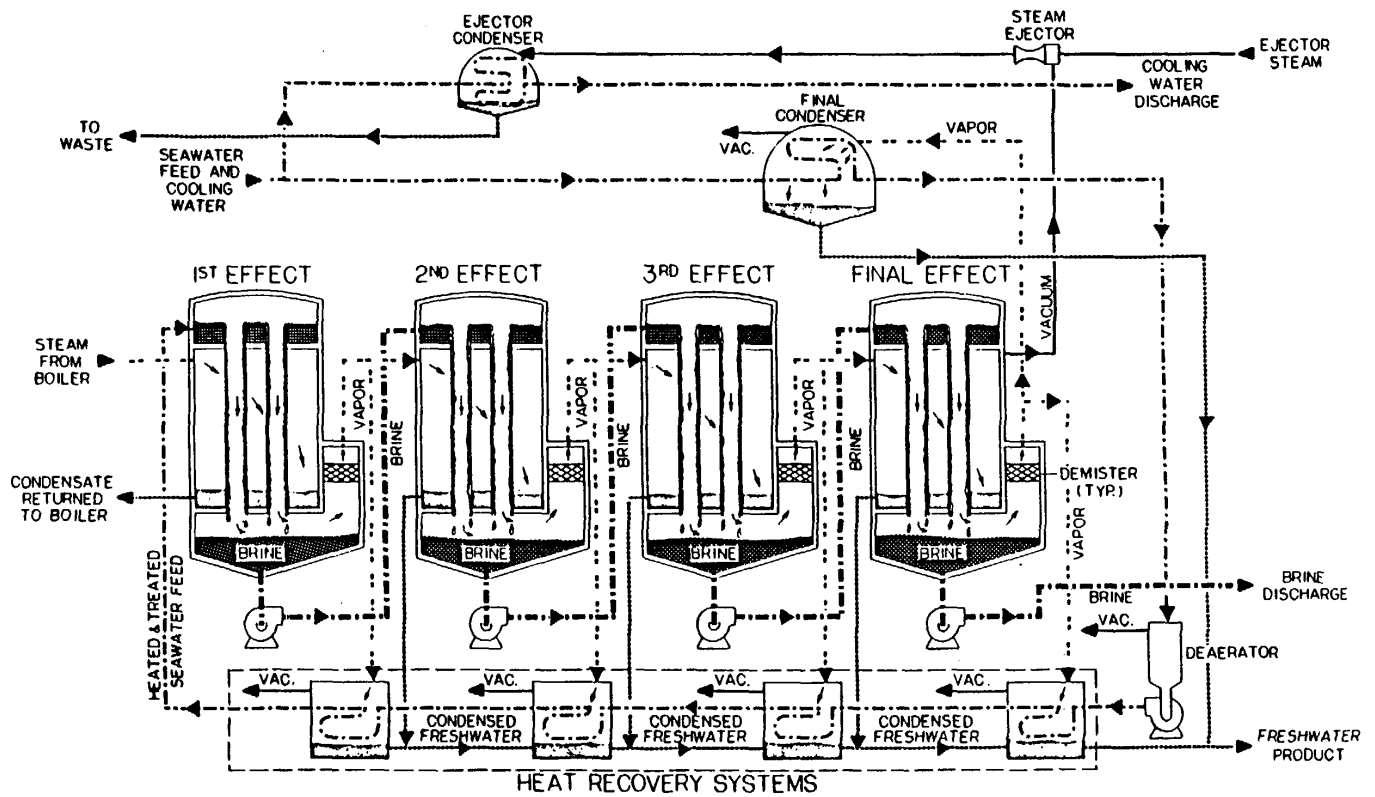


Figure 6-2. Multiple-effect vertical-tube evaporation process.

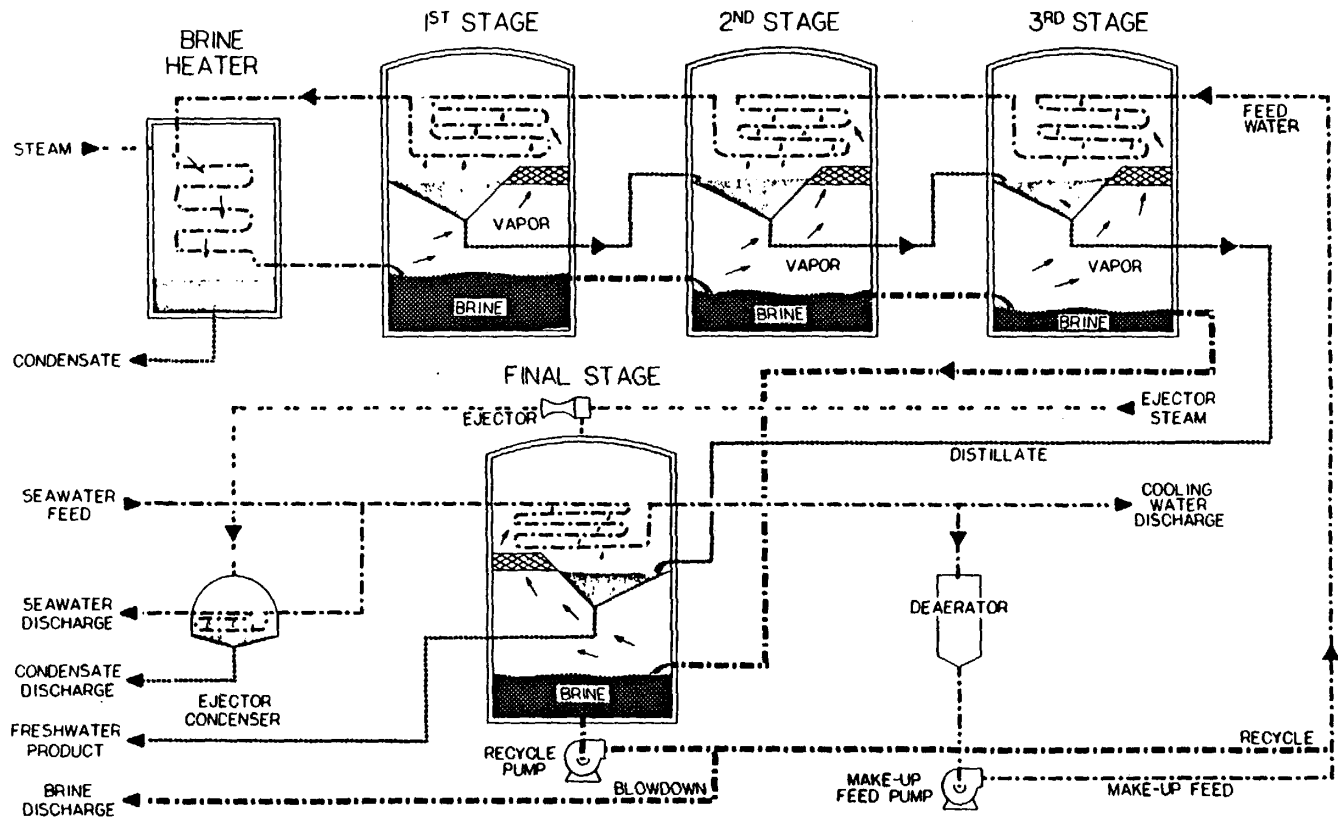


Figure 6-3. Multistage flash distillation facility.

distillation/condensation process. These systems are designed to maximize the production of product water with minimal energy input. A typical vapor-compression multiple-effect system is shown in figure 6-5.

The advantages of this type of system include a lower energy demand than high-temperature distillation, less corrosion due to possible use of thermoplastic materials, and lower operational temperatures.

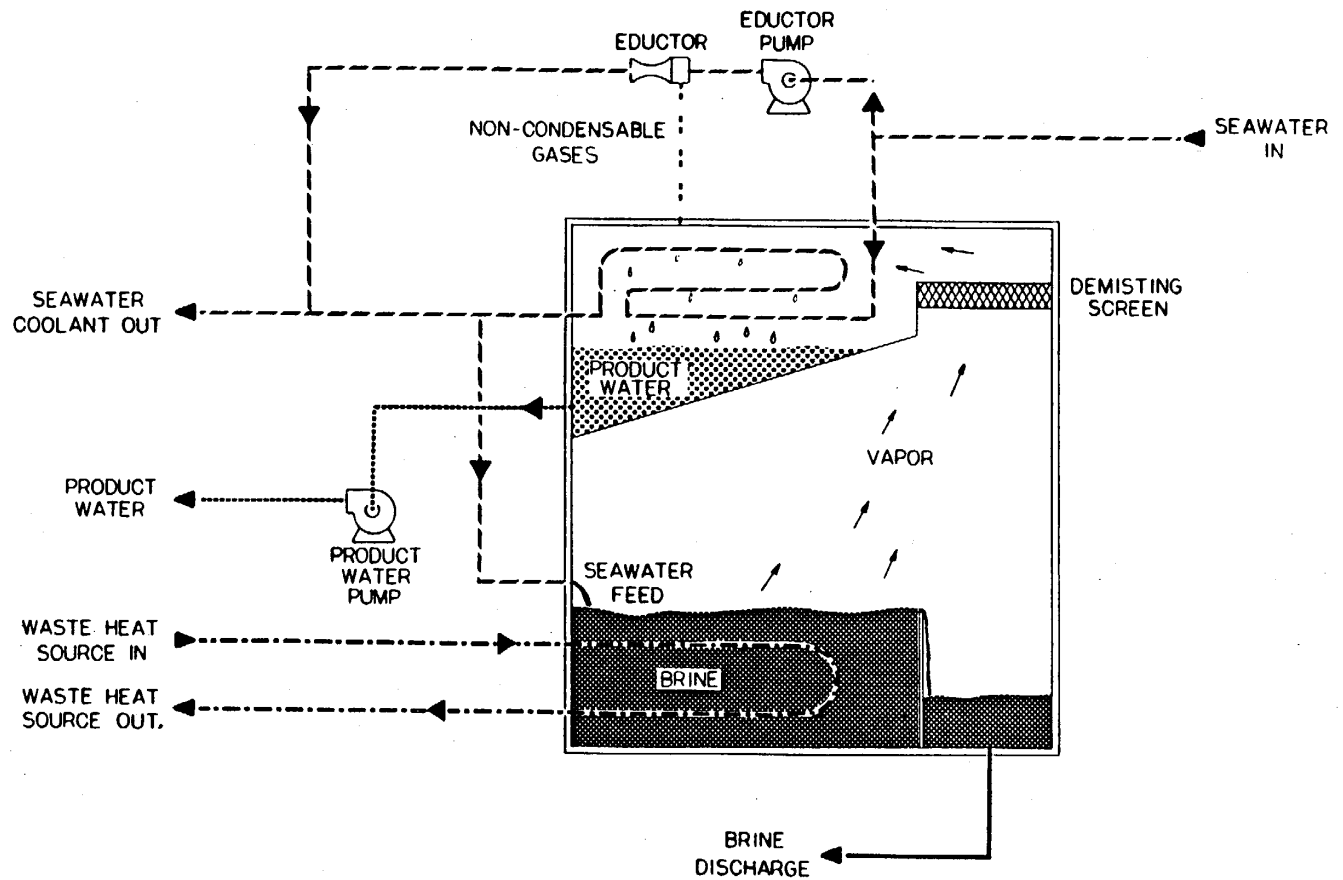


Figure 6-4. Waste heat recovery evaporation process.

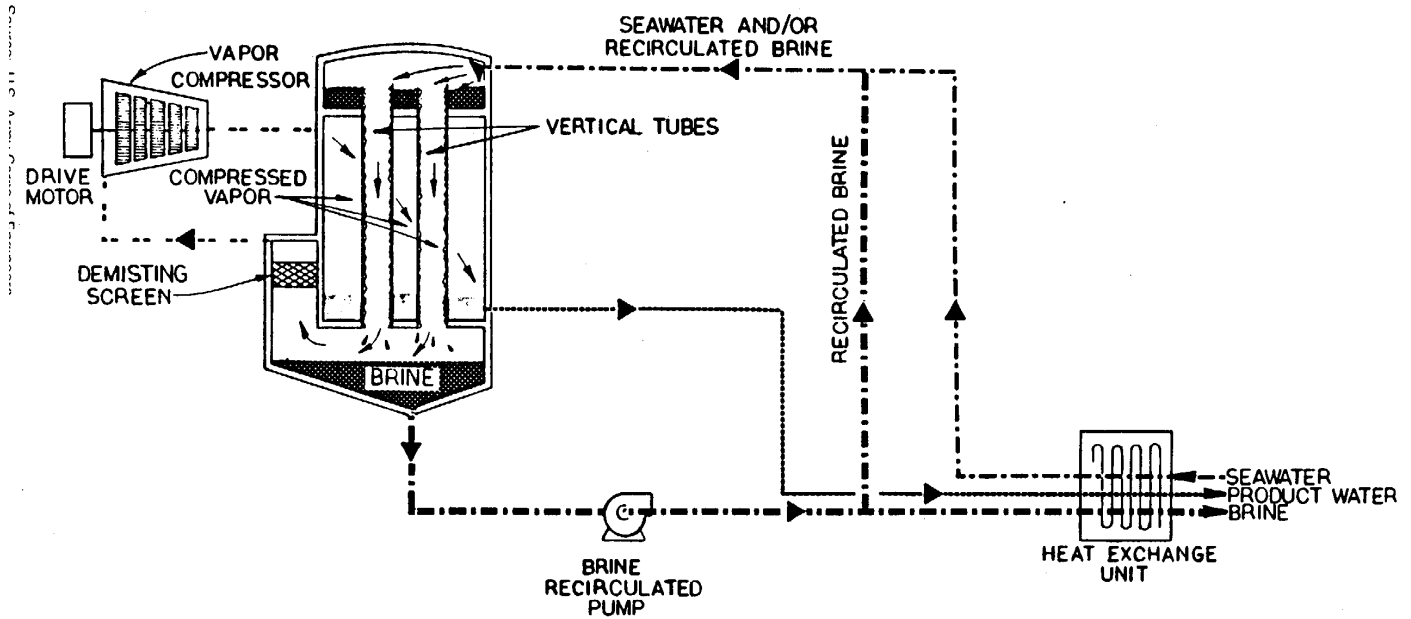


Figure 6-5. Vapor-compression vertical-tube distillation system.

6-5. Thermal discharge. A problem resulting from all distillation/condensation facilities is thermal discharge of liquids. Older high temperature facilities produce brine at very high temperatures. Cooling towers, heat exchangers, or similar equipment must be designed into the process to handle the thermal discharge from distillation/condensation facilities. More sophisticated desalination units employ a system of heat exchange devices that use the raw feed water to cool the brine and reclaim this waste heat to help provide thermal energy for system operation.

6-6. Design analysis. When it is necessary to review several water distillation/condensation designs, standard dimensionless analysis will be used for design comparison. If dimensionless correlations for particular aspects of design do not exist, a bench- or pilot-scale study should be done.

6-7. Materials of construction. The corrosive nature of high-temperature brines, acid pretreatments, and chemical scaling can cause plant failure. Presently, the only acceptable construction materials for wetted surfaces in high-temperature systems are an austenitic stainless steel, such as AISI Type 316L or titanium. Anodized aluminum and many thermoplastic materials are acceptable for use in low-temperature systems.

6-8. Distillation/condensation system design. Pursuant to finalized site and process selection, one distillation/condensation system will usually be chosen. When the process selection does not yield a single process, then designs must be prepared for more than one process.

a. Identification of work. When the base site has been selected and a schedule for construction has been prepared, this information will be made available to the water treatment engineer. The identification of the location and the time schedule will be considered in the design; this includes the date the system must be online. The minimum number and minimum size of the modules will be determined. Any restrictions that storage will place on maximum allowable downtime will also be determined. With distillation/condensation systems, the design must address the maximum allowable total dissolved solids and, where applicable, the minimum allowable rejection of distillable material. Distillable material is defined as nonaqueous, volatile water contaminants.

b. Existing or planned facilities. Distillation/condensation systems design must include availability of energy information. See sample problem A-8. Alternative steam sources considered in the design must include steam temperature, steam pressure, and available quantity of steam. The design must show available electrical power including voltage, amperage, phase of the available electricity, and frequency of the available electrical power.

c. Raw water information. One of two circumstances will limit the quantity of raw water consumed. Both of these limitations must be considered in the design:

- The availability of raw water may place a limitation on the raw water used in the process.
- The maximum amount of waste brine that can be economically disposed of may limit the raw water used in the process.

The principle requirement in a desalination design is an accurate projection of the chemical makeup of the worst quality water that will be used as raw feed water at the site being investigated. The design must include consideration of the maximum total dissolved solids, individual ions (see App. B), maximum amount of total suspended solids present in the feed water, maximum organic contaminant loading, and any gas or potential corrosive agent that may be in the feed water. All known or anticipated future qualities of the feed water shall be considered in the design.

d. Process design. When a distillation/condensation process has been identified as the most economical, then the design will be limited to the single process. The process design for any distillation/condensation process will include a minimum required input temperature and some maximum required heat sink temperature. Between these two temperature criteria, the process must be capable of producing the required product water quality and quantity. When a particular metallurgy is required for strategic, corrosion design, or economic reasons, this metallurgy shall be designated for all applicable parts, as well as spare parts. All required instrumentation must be included in the design. The design must show the required output water quality based on the worst raw water input chemistry and quality. The system design must be based on equipment with a history of successful water treatment system experience. The required experience history should include a minimum of 2 years of operating experience meeting water quality and system design

goals, treatment capacity, maximum allowable repair frequency and duration, and a maximum allowable ratio of experienced capital cost to repair cost.

The requirement for successful experience will limit the amount of untested innovation used at a facility.